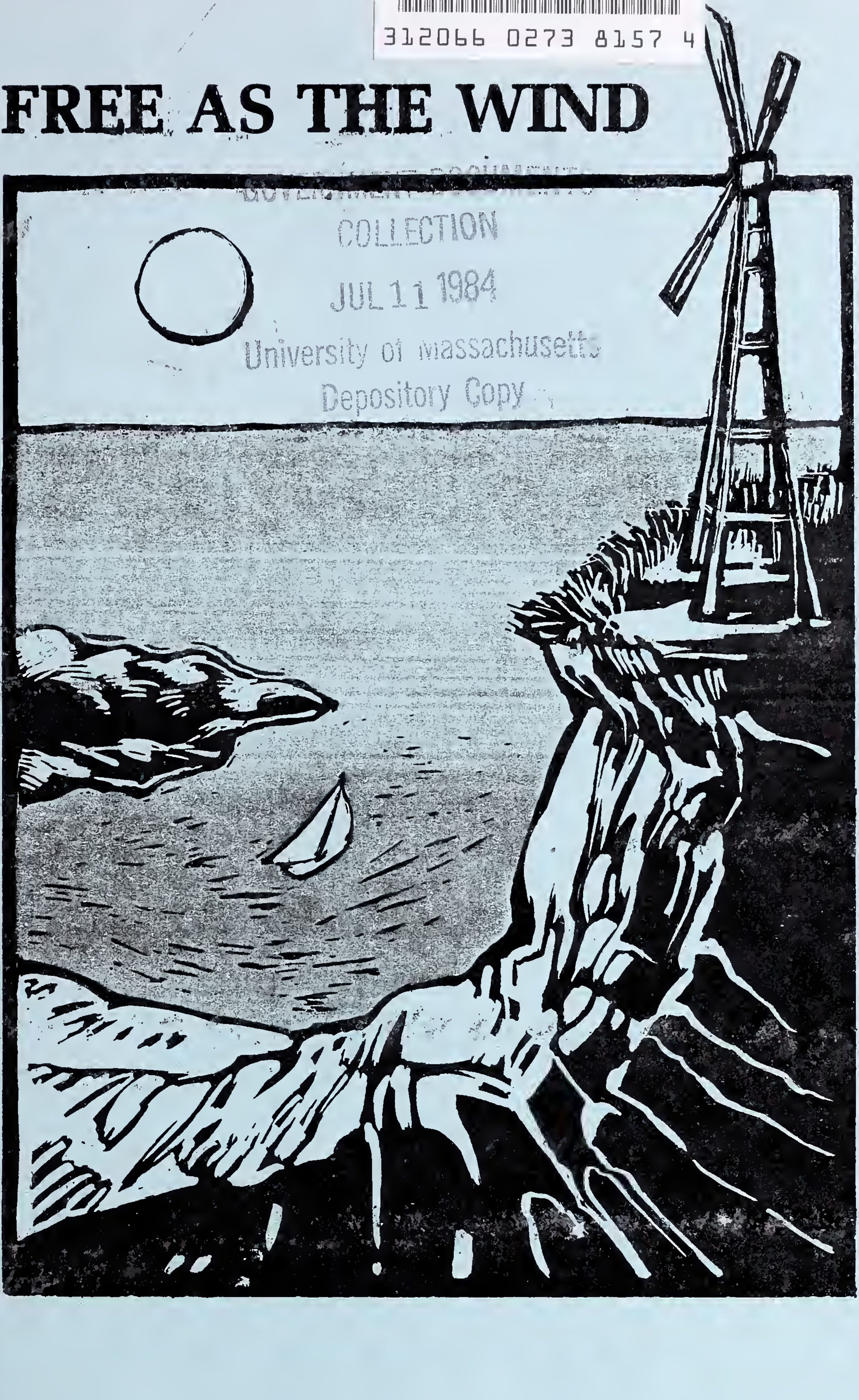
MASS. ER1.2: F87

UMASS/AMHERST
312066 0273 8157 4

FREE AS THE WIND



GOVERNMENT DOCUMENTS
COLLECTION
JUL 11 1984
University of Massachusetts
Depository Copy

COMMONWEALTH OF MASSACHUSETTS

MICHAEL S. DUKAKIS
GOVERNOR

SHARON M. POLLARD
SECRETARY

The Commonwealth of Massachusetts
Executive Office of Energy Resources
100 Cambridge Street, Room 1500
Boston, Massachusetts 02202

MICHAEL S. DUKAKIS
GOVERNOR
SHARON M. POLLARD
SECRETARY

(617) 727-4732

"Free as the Wind" is intended as a guide for Massachusetts homeowners considering the purchase of a windmill. This report represents the culmination of several months of intensive research by the staff of the Executive Office of Energy Resources, working closely with representatives of the wind industry, community groups and utilities.

The staff wishes to express particular thanks to John Plummer of Windmills, The Energy Store in Salem for his editing assistance and to Dr. Forrest Stoddard of Stoddard Consulting, Inc., in Pelham for technical advice. For their help in reviewing several drafts of this booklet we want to thank Gregg B. Amonette of Pinson Energy Corporation; Roger Bacon of the Massachusetts Municipal Wholesale Electric Company; Ross Bisplinghoff of Northeast Solar Energy Center; Eugene Butler of Energy Alternatives; Edmund Coffin of Enertech; Kenneth Cohn of Second Wind; Nancy Goodman of Fortier Energy Store; Lisa Limont of the Franklin County Energy Project; John Newsham of New England Electric System; Nelson Robinson of Cambridge Alternative Power; and Sandra Bodmer-Turner of U.S. Windpower.

Linda Sutliff, Director of our Division of Alternative Energy Technologies, is the principal author of this report. Johnathan Stroup, Phyllis Gardiner and Jane Carpenter Johnston assisted with research. Ruth Nee designed the lay out of the booklet, and George O'Neil prepared the interior illustrations. Cover art is by Marcia Sewall.

INTRODUCTION

The earth's winds swirl across her surface with a strength beyond the imagination. Winds blowing across the American continent move with a power 100 times greater than that produced by all the generating plants operating in the nation today.

Wind power is solar power. The sun heats each part of the earth's surface to a different temperature. During the day air over the Atlantic remains cool, as evaporating sea water absorbs the sun's energy. Air over the land warms as the land absorbs less of the sun's energy reaching its surface. Air heated over the land expands, rising as it becomes lighter. Cooler ocean air is denser, heavier. It flows over the land replacing the rising, warmer air with the refreshing breezes of a summer's afternoon. At night the land cools, the sea retains its warmth, the process reverses.

In much the same way, air over the equator warms under the tropic sun. Equatorial air rises, flowing to the poles, while cool, polar air travels to the tropics over the earth's surface. The earth's rotation whips these air masses, creating the prevailing westerlies that cause U.S. weather patterns to move generally eastward.

We have long recognized the power of wind, and have harnessed it to our own vocations. The first reported wind machines were built in Persia in 200 BC. They were used for grinding grain. Later wind machines were used for agricultural purposes throughout Europe. The surviving name "wind mills" is derived from the fact that the early use of the equipment was for milling grains.

Wind power has been used in Massachusetts for more than 300 years. The earliest European settlers arrived in 1620 on wind powered vessels. Wind power made Salem, Massachusetts the heart of East Indian trade, bringing treasures from half way round the globe for trade by local merchants.

When steam power replaced wind for long distance, commercial voyages, Massachusetts' builders did not abandon wind power. Today they fashion the world's finest yachts for cruising and racing. In lofts up and down Massachusetts' coast sail makers sew jibs and genoas, with new material, but based on designs that echo long-standing traditions.

Wind power is important to our agricultural heritage as well. Early windmills were used for grinding grain. The first in Massachusetts was built in Watertown in 1632.[1] Another, erected on Nantucket in 1786, still stands. Cape Cod is dotted with wind machines old and new that remind us of the self-reliance intrinsic to Massachusetts citizens.

The twentieth century's first American experiment with wind for generating large quantities of electricity was launched in 1941, on top of the 2000 foot high Grandpa's Knob near Rutland, Vermont. Mounted on a 110 foot tower, this modern wind machine generated 1 and 1/4 million watts of electricity in winds of 30 m.p.h. It operated for four years. A blade broke, and the then low cost of fossil fuels made it not worth repair.

Fossil fuels are no longer inexpensive. Massachusetts' heavy reliance on foreign suppliers for much of the oil we use flies in the face of our heritage of self-reliance. Throughout the Commonwealth all of us seek better ways to regain control of our own destiny. Many are thinking again about wind power as a way to meet the energy needs of a vibrant society.

---

[1] On August 14, 1632, it was moved to Copp's Hill in Boston because, according to Governor Winthrop's Journal, the machine could not capture the prevailing westerlies at the original Watertown site. See Nathaniel B. Shurtleff, A Topographical and Historical Description of Boston (Boston: Rockwell and Church, 1890), pp. 158-160.

"Free as the Wind" is presented to Massachusetts homeowners considering the purchase of a wind powered generator to produce electricity for household use. We will review the basic components of wind energy systems and how they work to produce electricity. We will discuss specific site evaluation techniques, helping you to determine just how much electricity a wind powered generator can produce at your location. We will look at the economics, the costs likely to be incurred and the return you can expect from such an investment. Finally, we will suggest a procedure for making a purchase.

Wind machines are not appropriate for all Massachusetts residents, but for some of you the use of a wind energy system represents a real opportunity to increase your self-reliance. We hope this guide will help determine whether a wind energy system makes sense for you.

TABLE OF CONTENTS

Page

INTRODUCTION i

I. EQUIPMENT BASICS 1

Figure I Horizontal and Vertical Axis Machines 3

II. PROSPECTING THE BREEZES 8

Figure 2 Region of Disturbed Air Flow 11

Figure 3 Common Anemometer Designs 13

Figure 4 Simple Method of Determining Turbulence 15

III. WIND-CENTS 16

Figure 5 Return on Investment Chart 23

IV. WINDMILL LIVING 26

V. THE FINAL PREPARATIONS 29

SUMMARY 31

APPENDICES

I. WIND DATA FROM NATIONAL CLIMATE CONTROL STATIONS IN MASSACHUSETTS 32

II. GRIGGS-PUTNAM INDEX 33

III. TABLE OF AVERAGE ANNUAL APPLIANCE CONSUMPTION 34

IV. WIND ENERGY SYSTEM OUTPUT 36

V. ECONOMIC ANALYSIS WORKSHEETS 37

VI. MANUFACTURER AND DEALER SELECTION CHECKLIST 40

I. EQUIPMENT BASICS

Electrical generators convert mechanical energy to electrical energy. Electric appliances adapt that electrical energy to your needs, releasing energy either as motion, as light or as heat.

Wind driven generators use the free flowing air as a source of mechanical energy. Wind generators are rated according to the amount of electricity they produce, measured in kilowatts. Each appliance is rated in terms of the energy it consumes, also in kilowatts. It is important, then, to balance the size of the wind generator with the demand which it will be called upon to support.

For example, a typical light bulb will use 60 to 100 watts of electricity. A solid-state color T.V. may require 200 watts. A hair dryer, or a small portable space heater may require 1500 watts. If, then, you want to dry your hair while watching television, with three or four lights on in the room, you will be using about two thousand watts (2 kilowatts, commonly expressed "kw") of electricity. And if you continue that activity for an hour, you will have consumed two kilowatt hours (kwh) of electricity.

A wind machine large enough to produce sufficient amounts of electricity to make a significant contribution to residential electricity consumption is usually capable of producing from 2 kilowatts to 10 kilowatts of electricity.

Wind machines capable of producing electricity for the home were built early in this century for use primarily in rural locations. With the advent of the Rural Electrification Act windmills became relatively inefficient and manufacture of wind driven generators was virtually discontinued for more than 25 years.

Today, however, nearly thirty manufacturers produce these devices in factories all over the United States. A few of these companies have to date dominated the industry, installing more than 400 systems.

With this rush of development characterizing the wind industry you may find yourself baffled by the claims and variety of designs to choose from. While you will want to learn in detail about a few models before you buy, it is helpful to begin by understanding the basic parts of a wind energy system and how they work.

All wind energy systems consist of three major components: A. the propellers (sometimes called rotor blades), B. the generator, and C. the tower. We will spend some time describing each of these in turn.

A. THE PROPELLERS

All wind machines have propellers which rotate on a shaft. Machines are classified according to the relative position of their shafts to the windstream. Machines whose shafts are parallel to the windstream and the earth are called horizontal axis turbines. Machines whose shafts are perpendicular to the windstream and the earth are called vertical axis turbines (See Figure 1).

Horizontal Axis Turbines:

Propellers on a horizontal axis turbine look like very large airplane propellers. If fact they operate on much the same aero-dynamic principles. Usually these propellers have two or three blades made of steel, wood, aluminum, or fiberglass. In the case of 2 kw to 10 kw machines, the propellers range from approximately 13 to 32 feet in diameter. The larger the propellers, the more power the machine can produce. Generally speaking, propellers two times as large will produce four times as much electricity in a given wind condition.

Horizontal axis turbines are designed to operate either upwind or downwind of the tower. If the machine is an upwind machine, the propeller blades face into the wind and the tower is on the leeward side. If the machine is a downwind machine, the opposite is the case; the propellers in a sense turn away from the wind. All modern horizontal axis wind machines track changes in wind direction by turning just as a weather-vane does.

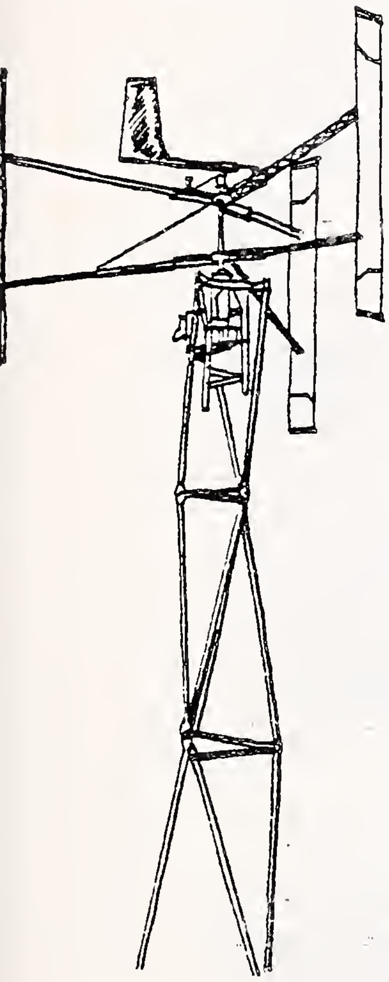
Vertical Axis Turbine:

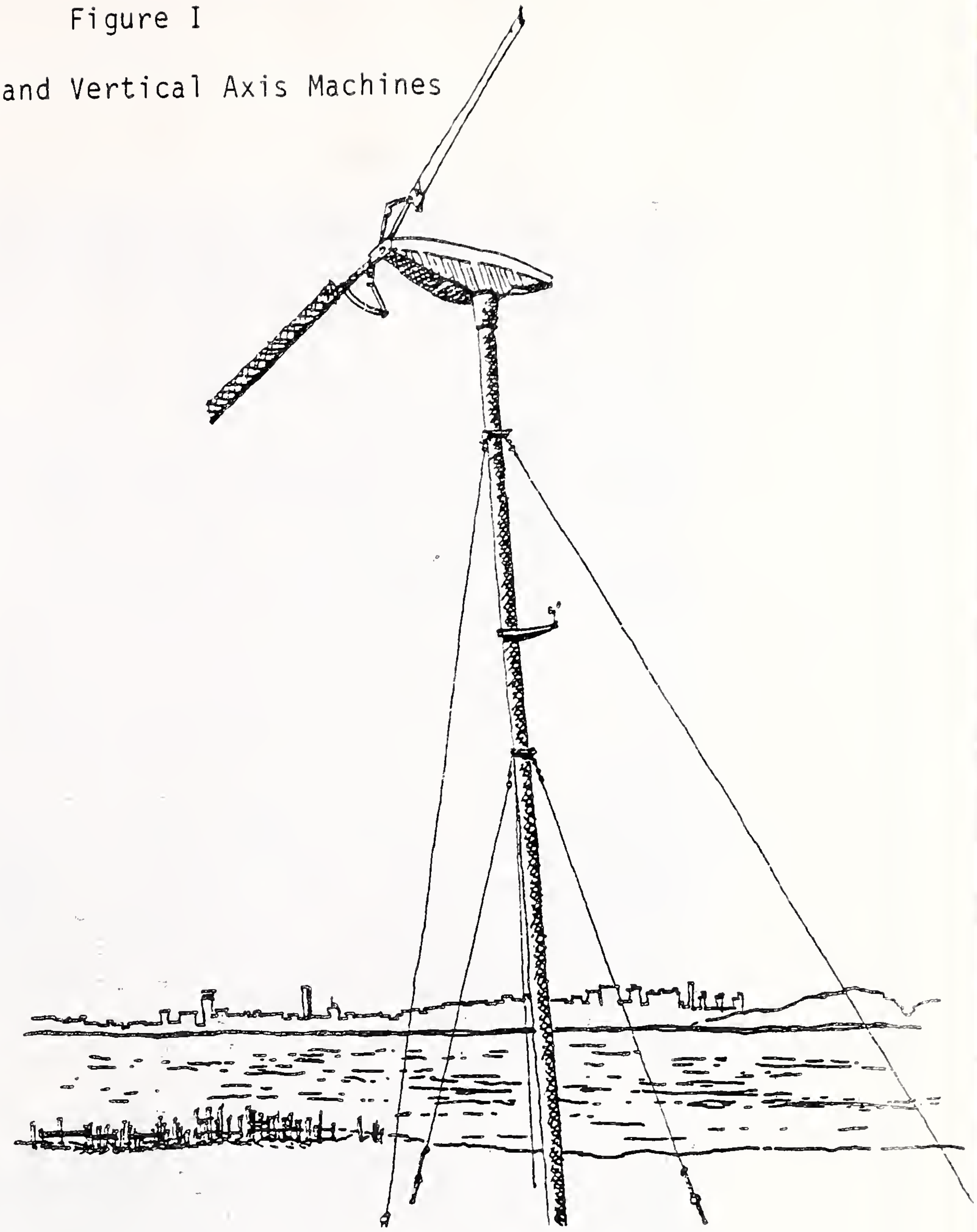
A vertical axis turbine consists of a shaft which is perpendicular to the earth and two or three blades. Vertical axis turbines operate on the same aerodynamic principal that allows a sailboat to tack into the wind. They are, however, capable of turning at speeds in excess of the speed of the wind. While horizontal axis machines need to turn as the wind direction changes, vertical axis machines do not.

Figure I

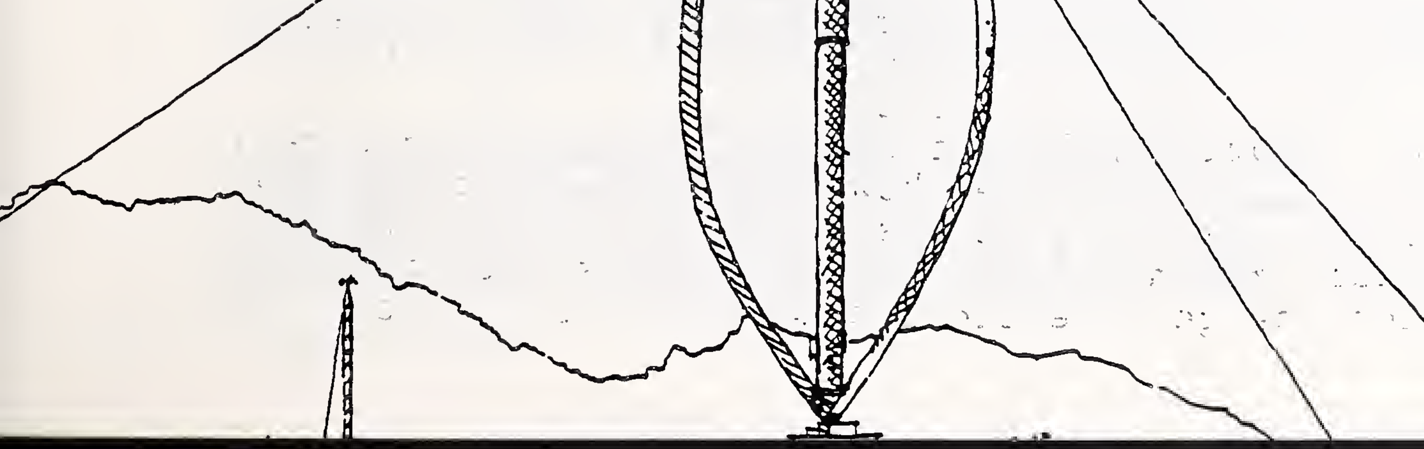
Horizontal and Vertical Axis Machines

Cyclo-Turbine with Lattice Tower





Double-Bladed/Horizontal Axis
with Guy-Wire Tower



Ø-Darrieus with
Guy-Wire Tower

One type of vertical axis turbine was developed during the 1920's by the French engineer, G.J.M. Darrieus. Darrieus blades curve out from the top of the shaft like the ribbons from a Maypole only to be attached again at the shaft's bottom. This creates the impression of a giant egg beater. Another type of vertical axis turbine is the "cyclo turbine". This design makes use of blades which are rectangular, vertical sails. Like horizontal axis machines the blades on a vertical axis machine may be made of steel, wood, aluminum or fiberglass. The larger the blades, the more power the machine can produce.

Propellers and Machine Output

Most wind generators are rated by the manufacturers in terms of their kilowatt production capabilities. It is important to note at what wind speed each machine is rated. Most wind machines begin to generate power when wind speeds reach 7 to 10 m.p.h. As wind speeds increase, and until the wind speed reaches the speed of the rated output, the amount of power a machine produces increases with the cube of the wind speed. Clearly, then, the amount of electricity a given machine will generate varies widely depending on wind speeds.

If a machine producing 10 kw at 22 m.p.h. begins generating power at 7 m.p.h., it will put out only 3/10 of a kw when it starts working at that wind speed. When the wind reaches 12 m.p.h., it will produce 1.6 kw. The output will continue to increase until the machine is generating 10 kw of power when the wind blows 22 m.p.h.

At 70 m.p.h. it may not produce any power at all. Above rated wind speed most wind turbines employ some mechanical device to slow down the propeller so that excessive power does not destroy the equipment. Some machines employ mechanical governors to absorb the excess wind energy. Other machines "feather" the propeller blades, turning them a little so as to spill the excess wind much as a sailor might luff a boat's sail during a windy squall. As a consequence electric power supplied by a wind generator does not continue to increase after rated capacities have been reached, at least not at the same high rate.

When wind speeds become excessive, usually in the neighborhood of 50 m.p.h., most machines simply shut down, much as a sailor flies a storm jib during a squall. This shutdown can be accomplished either by applying a mechanical brake, or by turning the blades away from the wind. No power will be produced by a wind generator during periods of exceptionally high wind speeds.

B. THE GENERATOR

The windmill's propeller, in either a horizontal axis or vertical axis design, turns a shaft connected to a generator. In most models, the shaft connects through a transmission or gear box which increases rotation speeds before reaching the generator. This allows the blades to operate at relatively slow speeds while absorbing the winds' energy at relatively high torque(force). Without this ability, the speed at which the propeller tips are traveling would soon exceed the speed of sound.

The electric power the generator produces will either be alternating current (AC) such as you need to run appliances or direct current (DC) such as your car produces or a battery stores. Nearly all residences utilize 60-cycle, 115 volt AC electricity, the type universally provided by the public utilities.

There are two basic types of generators: 1. DC generators, and 2. induction generators.

Generators producing direct current were part of the wind energy systems widely used in rural communities at the turn of the century. Even today such generators may be best for free-standing systems. That is, systems which do not interact with the public utility. Some local residents may want such a system because, in good Massachusetts tradition, they want the self-reliance of controlling their own energy source. Others may be located too far from a utility power line to make interconnection feasible.

If you have either need, you will want to connect your system to batteries for electric power storage. Batteries for such stand alone wind systems are much like car batteries. They can store more power, however, and they can be recharged more times. But like auto or marine batteries, they store DC power and can accept the output of a DC generator directly.

If the demand placed on the system is large, the batteries will need to be large as well, and these can require a substantial dollar investment. Generally batteries for windmills should be of sufficient capacity to maintain the electrical needs of a home for at least three days.

Batteries themselves present special installation and maintenance requirements. While we don't have the time to go into detail here, we would be remiss unless we said that batteries should be stored inside, off the floor and in a well-ventilated place where neither children nor pets play.

To use the direct current produced by a DC generator or released by a battery storage system, you need either to have appliances that use direct current or to change the direct to alternating current. It is possible to purchase DC appliances. An extensive array of such equipment is manufactured for use in mobile homes, campers, boats and other instances in which standard utility current is not available.

In most residential applications, however, you will want a system that produces alternating current. You will need to purchase a synchronous inverter to convert DC to AC. If your system is a free-standing one, the inverter converts the power after it is released from the batteries. If you retain grid interconnection, the inverter should be installed so as to alter the current when it is produced by the wind energy system.

An induction generator is much like an electric motor. The magnetic field for the induction generator is produced by electricity drawn from the utility power line. As a result, the power produced is always synchronous with utility line power. If the machine is properly designed, it will draw utility power when wind speeds are just about high enough to start up the propellers. As the wind speed increases, the blades turn faster and the machine begins producing power. The amount of power produced varies with the cube of the wind speed, but the power itself is always 60 cycle, 115 volt AC electricity.

C. THE TOWER

The final major component of a wind energy system is the tower. A tower accomplishes three purposes:

1. It keeps the wind machine's blades off the ground for safety
2. It raises the machine high enough into the air so that its operation is unaffected by the wind turbulence caused by obstacles on the earth's surface

3. It permits the propellers to take advantage of higher wind speeds usually found at greater heights.

Wind machine towers are usually between 60 and 100 feet high. They may be either guyed or free-standing. Guyed towers usually cost less, but because they have to be anchored they take up more space. Guy wires usually extend from the base of the tower to a distance equal to roughly half the tower height.

Free standing towers are usually made of steel in a lattice work design. They are anchored into the ground usually with concrete. In some New England locations they may be anchored directly to exposed bed rock.

Towers may seem like an invitation to go climbing. Their bottom ladder rungs should be removed to make climbing more difficult. Like swimming pools they can be surrounded by a fence or a healthy planting of very prickly shrubs to keep neighborhood children and curious adults away.

Manufacturers specify the type of tower which should be used with their machines. It is very rare indeed for a tower designed by a responsible manufacturer to fail. It is, however, extremely important to follow manufacturers' suggestions carefully. Wind machines vibrate. Manufacturers recommend towers designed to tolerate vibration to maximize safety.

If you have an old tower in your backyard you should not assume it will be adequate for a wind machine. In fact, you should both check with your manufacturer and have an engineering study performed before you decide to use it.

Because wind machines can vibrate, they should generally not be roof mounted. Major structural damage to your house can result.

Wind energy systems are relatively simple. Once you have in mind the few basic principles described above, you should be able to evaluate the various machines presently on the market. Before you begin to shop seriously for a windmill, however, you need to consider whether you have a good location for one.

II. PROSPECTING THE BREEZES

If you decide to purchase and install a wind energy system, you will become something of a prospecter. You should begin, if you will, by prospecting the breezes.

Some new businesses really do prospect for wind in much the same way as the "49ers" did for gold. These companies are in the business of producing electricity with wind and selling the power to a local utility. The wind machines may be quite large, capable of producing as much as 4 megawatts of power (4 million watts). In some cases the wind machines may be relatively small, but spread out in arrays (wind farms or parks) which in the aggregate can produce a large amount of electricity.

These companies search for a site with the best wind regime and topography for their equipment. You probably can't be so choosey. For the homeowner the question more often is whether there's a spot in the backyard that's well suited. To answer that question you need to know how wind interacts with a wind turbine, what types of places are generally best, and how to assess wind speeds at your own specific site.

THE WIND ITSELF

The amount of power in a given wind stream will be half the air density, times the area of the propellers, times the cube of the wind speed. The denser the air is, the more power a wind machine can produce. Air is denser at sea level than it is on top of a mountain. The larger the area of the propellers, the more power the machine will produce. Most importantly, the faster the wind moves, the more power is in the wind stream.

Because the output of a wind machine is so sensitive to wind speed, it is hard to over-emphasize this point. Recall the earlier example of a machine designed to produce 10 kw at 22 m.p.h. It produces only 1.6 kw at 12 m.p.h.; at 14 m.p.h., it produces 2.6 kw; at 18 m.p.h., it produces 5.5 kw; and at 20 m.p.h., it produces 7.5 kw. At half its rated speed, a wind powered generator produces only a little more than 12% of its rated output. Because the amount of power you actually get depends to such a great extent on wind speed, you can't just assume you have enough wind. It's worth taking the steps necessary to find out just how much wind there is at your location.

A GOOD PLACE

A good place for a wind machine is one where you can expect a non-turbulent wind stream moving at an average speed of at least 12 m.p.h. over the course of a year.

Wind machines should be located where the air is not turbulent. It is difficult for wind machines to extract power from turbulent air masses. Turbulence exerts great strain on the equipment. Stress will shorten the life of the equipment and can result in frequent, costly repairs.

Massachusetts does have many windy spots. In fact, Boston is said to have the highest wind speeds of any city in the country. Around the state, according to data from National Climatic Centers, average wind speeds vary from 7 to 16 m.p.h. at 33 feet above ground (See Appendix I). Many locations are then quite good prospects, many others are not.

The best places for wind machines in Massachusetts are generally expected along the coast, or on unobstructed western exposures in the Berkshires. More generally, good wind sites are to be found:

- across open plains and along shorelines especially where the water is between the site and the direction of the prevailing winds
- in mountain gaps where wind is funneling
- at the top of well rounded hills with gradual slopes
- on coastal islands
- at high elevations
- in valleys that lie in the direction of the prevailing winds

Even in these places, however, wind can be interrupted, diverted or slowed by such features of the landscape as hills, valleys, trees, buildings, or any formation natural or man-made which diverts wind flow or creates turbulence.

To assure a smooth flow of air, a wind machine should be raised 30 feet above any obstacle within a 100 yard radius (See figure 2).

ASSESSING WIND SPEEDS

If your backyard is a place where high wind speeds can be expected, you may have a good location for installing a windmill. In order to select a wind machine of the proper size, you will need to measure the actual wind speed. There are three approaches to measuring wind speeds. As you might expect, the easiest ways are also usually the least accurate.

1. Use available wind measurements: If you live near an airport, a Coast Guard station or some other weather recording station, you can write to the National Weather Service and ask for information about your area's wind speeds.

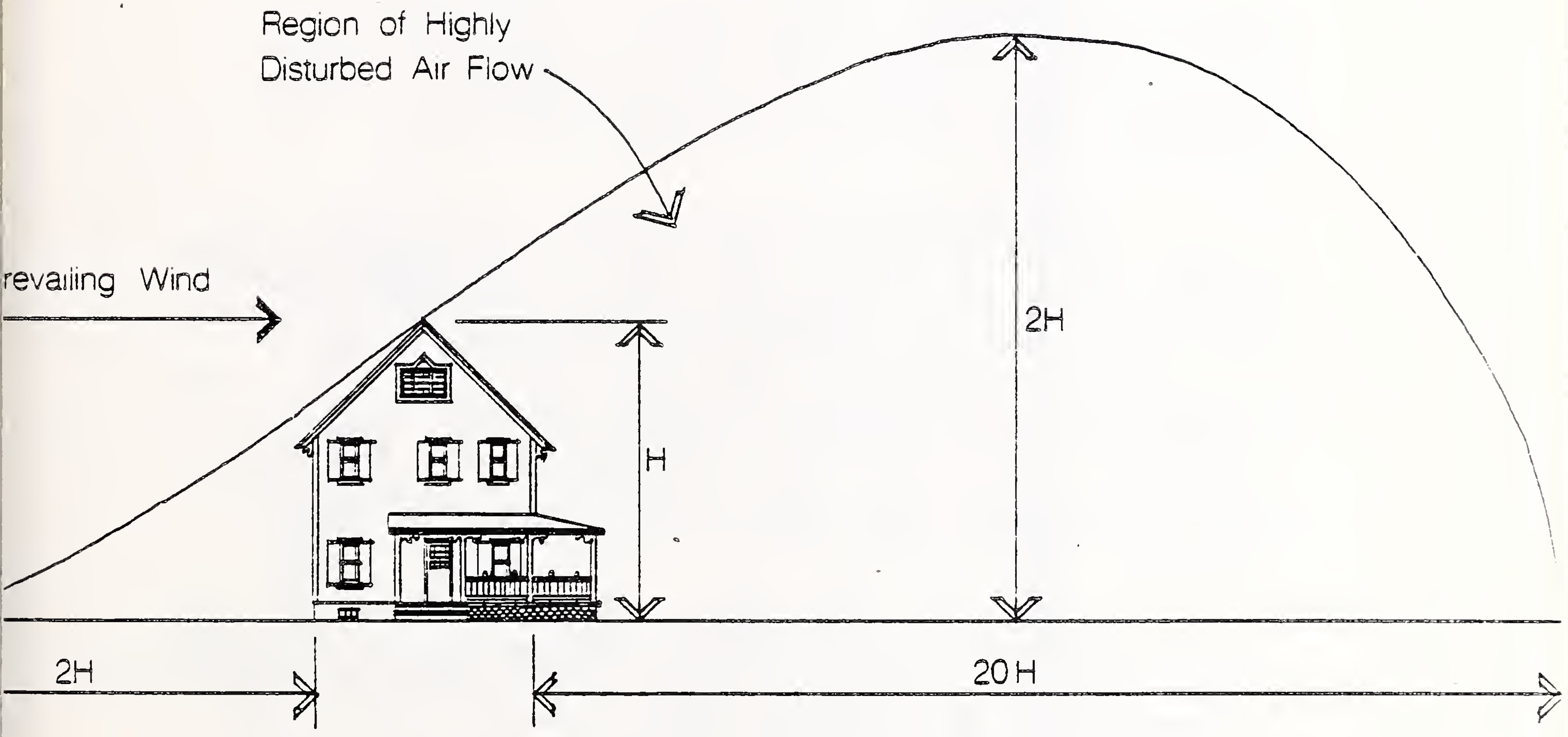
Unfortunately, however, what they tell you may not be too helpful. In fact, their data may actually be more discouraging than it should be. Data may well have been collected at a height considerably lower than the one you would use for a wind machine. As we have said, wind speed increases with height. Furthermore, most weather stations record wind data less frequently than is desirable for survey purposes.

If the terrain between your site and the weather recording station is relatively flat, data can be correlated with data from recording stations as much as ten miles away. In hilly, rugged, terrain, however, such as we have in much of Massachusetts, this method of assessing wind speeds just won't be sufficiently reliable.

2. Use ecological indications: Constant exposure to wind blowing from one direction deforms evergreen trees. The Griggs-Putnam Index (See Appendix II) evaluates wind speeds by assessing the degree of deformity of balsams, firs, or spruces at a given site. This index is site specific, and it is based on considerable assessment experience. It is best used, however, to help determine whether your site is worth the time and costs associated with a full wind data collection and analysis effort.

Figure 2

Region of Disturbed Air Flow



Region of Disturbed Air Flow Over a Small Building

3. Conduct a wind survey: Far and away the most desirable approach to evaluating wind conditions at any site is to conduct a wind survey at that site. This involves the measurement of actual wind speeds at the site for an extended period. To assure an accurate assessment a full year of data should be collected.

You may be able to extrapolate measured wind speed by correlating your information to that collected at a nearby weather station. Suppose average wind speeds at your site are, say, 14 m.p.h. over a three month period, and just 12.7 m.p.h. at a nearby airport during that same period. You may assume, if the terrain between your site and the weather station is reasonably flat, that average wind speed at your location is 10% higher than that at the local airport.

Wind speeds are measured by wind site assessment systems. These systems consist of two parts: the anemometer which may or may not include a wind vane (See Figure 3 for illustrations of common anemometer designs and of mounted anemometer); and the data collector.

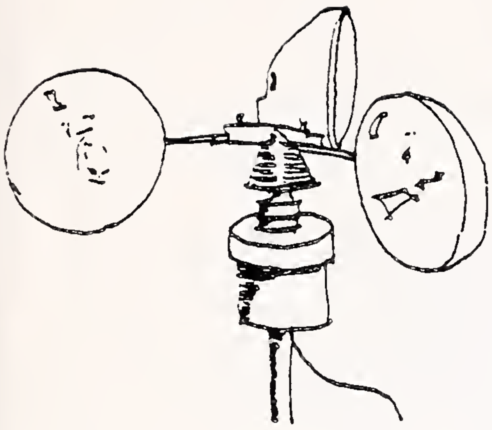
Wind frequency distribution is important in estimating the output you can expect from a wind energy system. Take two sites, each with an average wind speed of 15 m.p.h. Suppose that at one the wind speed is a constant 15 m.p.h.; at the other wind blows 10 m.p.h. half the year and 20 m.p.h. the other half. The second site will produce at least 33% more energy than the first. As you may have already calculated, this results from the fact that the output of a wind energy system increases more than proportionately with the increased speed of the wind.

It is best, therefore, to use a recording wind site assessment system. Such a system records both the average wind speed and the distribution of wind speeds at your site. This record can be entered into a computer to extrapolate very accurate estimates of the electricity production which can be expected from any of a number of wind machines which might be installed at that site.

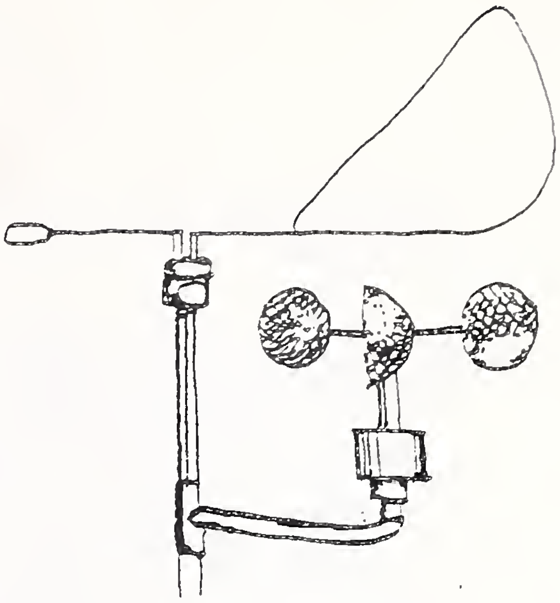
Included in your wind survey should be some estimate of wind turbulence. Sophisticated equipment exists for this purpose as well. You may, however, get adequate results simply by flying a kite. Tie bright red ribbons (they're easiest to see) at intervals on the kite string. Where it's turbulent, the ribbons will ripple and twist. Be sure to check particularly

Figure 3

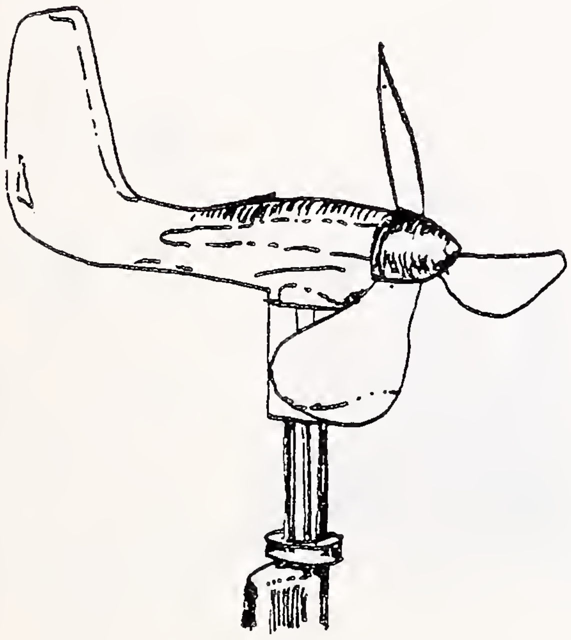
Common Anemometer Designs



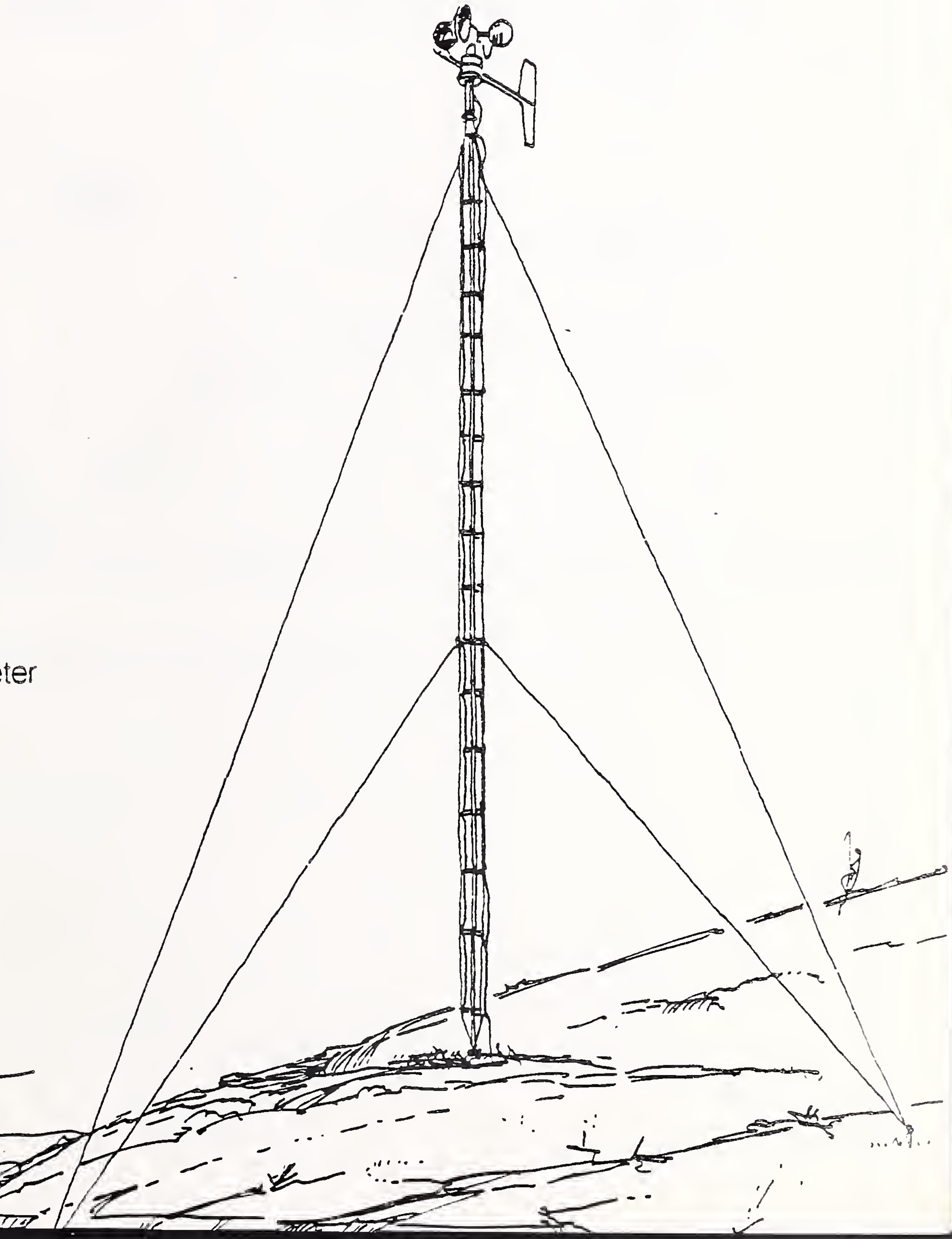
Wind Cup Anemometer



Wind Cup Anemometer
with Wind Vane



Propeller-Type Wind Anemometer



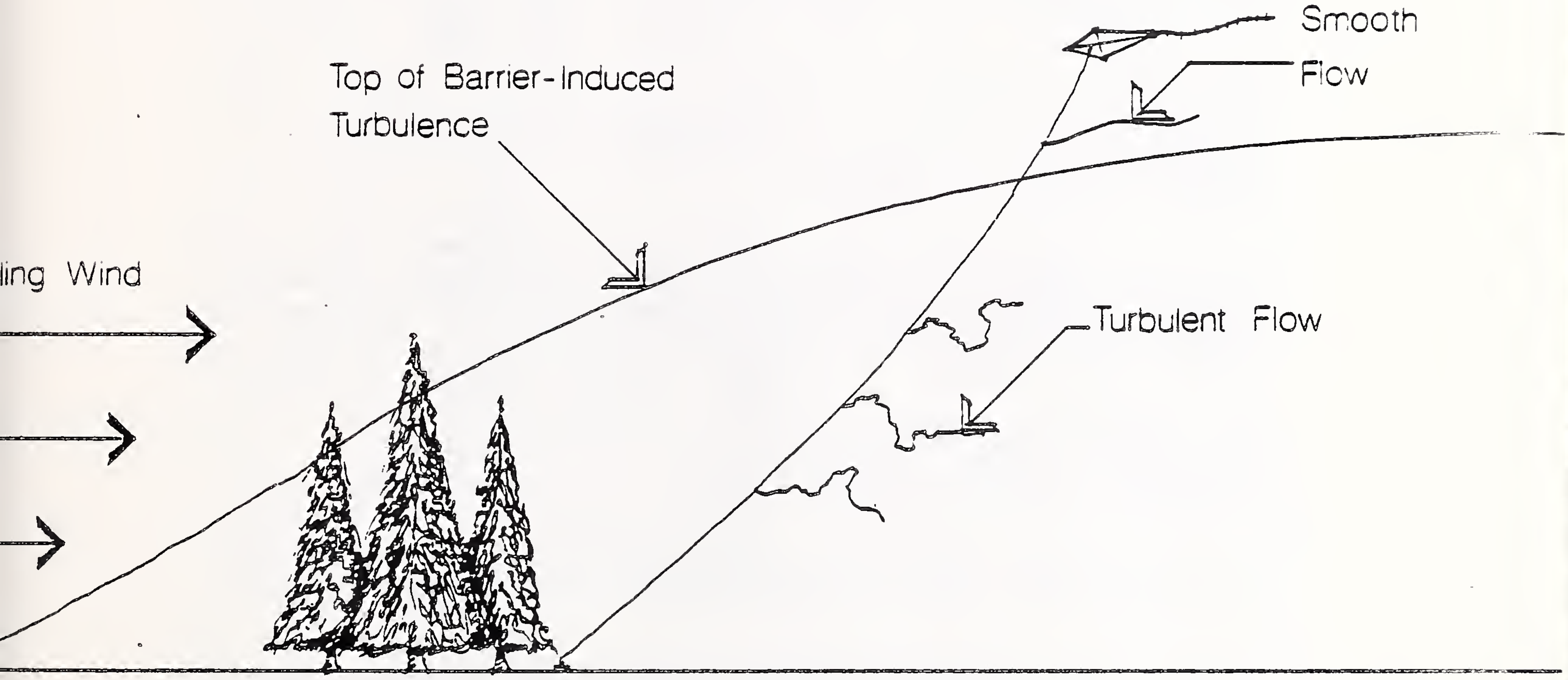
the predominant wind direction for turbulence (See Figure 4).

You may want to have a wind survey conducted by a professional survey firm. Such a survey will cost from a few hundred dollars to about one thousand dollars, depending on your location, the length of the survey period, and the level of detail. Should you decide to conduct your own survey, equipment can be purchased or rented for a few hundred dollars. Personnel where you obtain this equipment can advise you on its installation and the interpretation of results.

Your wind survey will require time, money, and a good measure of patience. But then, prospecting always has.

Figure 4

Simple Method of Determining Turbulence



Simple Method of Detecting Turbulence

III. WIND-CENTS

Evaluating a windmill involves a different kind of thinking than you use with other appliances. When you're buying a refrigerator you look for one that will give you the most wanted features for the lowest price. You may consider maintenance and operating costs, but many people simply do not.

Buying a wind machine involves thinking about the purchase in another way. You will incur a fairly large expenditure when you buy the system. The fuel for using it, the wind, is free. You want to be as certain as possible, however, that operating and maintenance costs will not exceed your fuel savings, that your savings will be large enough to warrant your initial expenditures.

The purchase should be considered, then, like an investment. You should invest with the idea of receiving interest on your investment in the form of lower electric bills during the entire time you own your wind system. It makes economic sense to buy a wind powered generator only if that interest, or return, is high enough to warrant the initial costs and maintenance charges you'll incur.

To assess the economic potential of a wind machine, you need to answer the following questions:

- How much electricity do you use? How much is that electricity likely to cost over the next ten or twenty years?
- What size machine will produce the needed electricity at your site? What is the dollar value of the power you produce?
- What is the cost of that machine installed? What is the estimated annual maintenance cost for it?

With the answers to those questions, you can estimate the return or interest you'll realize from an investment in a wind machine. You can then compare that return with the interest you could expect if you invested the same money in something else.

HOW MUCH ELECTRICITY DO YOU USE?

The easiest way to determine how much electricity you are now using is to review your electric bills. If you don't save old electric bills, your utility can send you copies. Generally, if you use electricity for appliances and lights only, you average about 500 kwh/month or 6,000 kwh/year. If your water heater is electric, add another 200 kwh/month or 2400 kwh/year. Electric heat adds about 1,200 kwh/month or 14,400 kwh/year. Clearly, then, if you have an all electric house, you'll need a much larger wind machine to satisfy all your demands than if you use electricity only for lights and appliances.

Many appliances and light bulbs tell you how many watts of power they use. A 250 watt light bulb, for example, uses 250 watts of power or .25 kilowatts (kw). If you leave it on for an hour, it uses .25 kw x 1 or .25 kilowatt hours (Kwh). If you run it 2 hours a day for a month (30 days), it uses .25 kw x 2 hours. x 30 days or 15 kwh. If your electric company charges you 8.5¢ per kwh, lighting that bulb costs you about $1.28 per month.

Suppose you really don't need the part of the room where the light is to be that bright. You buy a 100 watt bulb. It uses .1kw x 2 hours x 30 days or 6 kwh. At 8.5¢ per kwh, you'll pay 51¢ per month to run the new bulb. Your savings is already 77¢ per month.

Take last month's electric bill. List beside it each of the appliances and lights you used. Each one should tell you how many watts of power it draws. In case yours doesn't, we've included a list of the most commonly used appliances and the power they use as Appendix III.

Now figure out how much your electric company charges you for each kwh. To do that, divide the total you paid (that includes the Fuel Adjustment Charge) by the number of kwh they say you used. Multiply each appliance's power utilization in kwh by the cost per kwh. That's how much it costs you to use each appliance.

You will probably see immediate ways to reduce your electricity consumption. For example, the dishwasher uses 1200 watts and takes one hour to run (a half hour for washing; a half hour for drying). Suppose you use your dishwasher once a day, everyday. That's 36 kwh a month. If your electricity costs 8.5¢ per kwh, $3.06 of your electric bill can be attri-

8.5¢ per kwh, $3.06 of your electric bill can be attributed to washing dishes. Dishes will dry without the drying cycle if you leave the door ajar. It takes longer, but most days you're probably not in a rush. Simply by opening the door at the end of the wash cycle every time you do the dishes, you can save $1.53 each month.

After you have completed this analysis and made changes in how you use electricity, you'll know how much power you genuinely need.

WHAT SIZE MACHINE CAN PRODUCE THAT MUCH POWER AT YOUR SITE?

As we have discussed, the amount of power a wind energy system can produce is related both to its own rated output and the site's average wind speeds. The chart in Appendix IV provides an estimate of the number of kwh's a machine with a given rated output will produce at a given annual wind speed. The chart is a useful one for making an initial evaluation of energy production. For a more accurate estimate, however, you should seek additional information on machine output from the manufacturer.

For example, suppose that at your site annual windspeeds average 15 m.p.h. In the summer, however, average wind speed is only 10 m.p.h., but during the winter this increases to 20 m.p.h. According to the chart a 2 kw machine operating for six months in average winds of 10 m.p.h. can produce 1,400 kwh. Operating for six months in average winds of 20 m.p.h., it can produce 4,550 kwh. So at a site with annual average windspeeds of 15 m.p.h. a machine rated at 2 kw would produce 5,950 kilowatt hours of electricity annually.

Utilities are required to purchase electricity you produce and do not use. A federal law, the Public Utility Regulatory Policies Act of 1978 (PURPA), requires your utility to pay you the costs it avoids by not having to produce the power itself

This law requires each state to develop its own system for controlling sales from small power producers to local utilities. In August of 1981 the Department of Public Utilities issued regulations governing such sales in Massachusetts.

Here in the Commonwealth, the owner of a residential wind machine with rated capacity less than 30 kw has two choices:

1. A meter may be installed, at the owner's expense to measure the electricity used in the home less that produced by the wind machine each month. For each kwh metered the utility will pay a price equal to all costs it avoids as a result of the purchase. The price paid may or may not be as great as the price you pay per kilowatt hour.

2. You may connect your windmill to your existing electric meter causing your meter to roll "backward" when you produce more electricity than you use. In this case the price paid by the utility is equal to the price it charges when you use more electricity than your windmill produces and the meter rolls "forward". Essentially you are using the utility system to store power for you. Under Massachusetts regulations, however, during a month in which you produce more electricity than you consume you are not able to receive a credit for the balance. Under this option, there is then, no benefit to be derived by installing a very large wind system to produce more power than you use.

Return to our earlier example. A 2 kw machine operating in average wind speeds of 15 m.p.h. would produce about 5,950 kwh per year. Selecting the second option, the dollar value of the power produced will be 5,950 times the per kwh price. If the current price of electricity is 8.5¢ per kwh, the electricity generated has a value of $505.75.

What Is The Cost Of A Wind Machine?

Three major costs need to be considered in evaluating the total cost of a wind energy system. These include: a) the cost of the wind generator itself, b) installation costs including the tower, instrumentation and labor and c) the cost of maintaining the system.

Wind powered generators can be purchased for as little as $4,000 for a 2 kw machine, and can cost as much as $15,000 or more for a 10 kw wind generator. The larger machine costs more, but the cost per kw of capacity will be less for larger machines.

Installation costs will be nearly the same for a wind generator of any capacity. Tower height is determined by surrounding terrain and wind conditions. Larger inverters, if you need one, do cost more, but other instrumentation costs are essentially fixed. The work involved in installing a wind system is, within the range of residential machines, also independent of generator size; consequently labor costs are fixed.

Standard maintenance costs such as lubrication and other periodic repairs are similarly independent of machine size. In the event of equipment failure, however, larger machines are likely to require more expensive repairs. Should a blade shatter, for example, a ten foot blade is more than twice as expensive to replace than a five foot blade.

Overall, the following will provide an estimate of what a wind powered generator will cost:

1. $1,000 to $2,000 for each kw of generator capacity with smaller generators tending toward the high end of that range.

2. $3,000 to $5,000 installation cost, depending on tower height requirements, instrumentation and terrain.

3. 1% to 5% of initial purchase price annually for maintenance. This, as we have discussed, depends in part on site conditions, but is clearly dependent on a number of other factors. Perhaps most important is how much maintenance you are prepared to do yourself.

There are both Federal and State tax credits which apply to the purchase of a wind generator. Subject to certain exceptions (you should check with your own tax adviser), the following rules apply:

1. 40% of the first $10,000, up to $4,000, may be deducted from your Federal income tax.

2. 35% of the balance, up to $1,000, may be deducted from your State income tax.

Again using our example, a 2 kw machine might cost as follows:

1. Purchase price: 2 kw at $2,000/kw $4,000

2.	Installation on 60' tower	$4,000
	TOTAL installed cost	$8,000
3.	Federal Credit = 40% of total	$3,200
	Balance after federal credit	$4,800
4.	State Credit = 35% of balance (with $1,000 limit)	$1,000
5.	After tax credit purchase price	$3,800

Maintenance costs for a wind system of this type are hard to predict. For this example we have assumed 2.5% of the purchase price or $200 per year.

EVALUATING YOUR INVESTMENT

When evaluating a wind energy system as an investment the important question is this: Will an investment in a wind generator provide a greater financial return than other investment opportunities? Of course there may be other, non-financial criteria. These are, however, matters of personal judgement about which there can be neither dispute, nor objective advice.

Financial analysts have developed an approach which takes into account many of the factors which should be considered when evaluating an investment of this type. They call this the "return on investment". The "rate of return" has a meaning similar to that of an interest rate. Don't let these terms confuse you. While the arithmatic involved is a little complicated, the ideas are straight forward and relatively easy to grasp.

What are the factors which should be included in determining return on investment? First, there is the size of the investment itself, the purchase price less applicable tax credits. In our example this is $3,800, the net investment.

Second, there are the savings expected, less operating and maintenance costs. In our example we projected the first year value of the electricity produced to be $505.75. From this, however, we should deduct the anticipated maintenance cost of $200.00, for a net saving of $305.75. Dividing that net savings by the net investment ($305.75 ÷ $3,800.00), indicates a first year return of 8%.

But we are not quite finished; two more factors are important. First is the expected life of the equipment being purchased. Clearly, if the windmill in our example should last only 4 or 5 years, we would not "get our money back," or, in more technical terms, we would never achieve "cash-flow breakeven." But a well-designed and well-maintained wind energy system should last at least twenty years. So we'll use the twenty years as our "planning horizon."

One final factor is important -- inflation! During the past decade the cost of a kwh of electricity has gone up slightly more than 70%. Will that inflation rate continue? Of course nobody knows for sure. But it is as a hedge against inflation that you are considering this investment, so some estimate of what that inflation rate will be is needed.

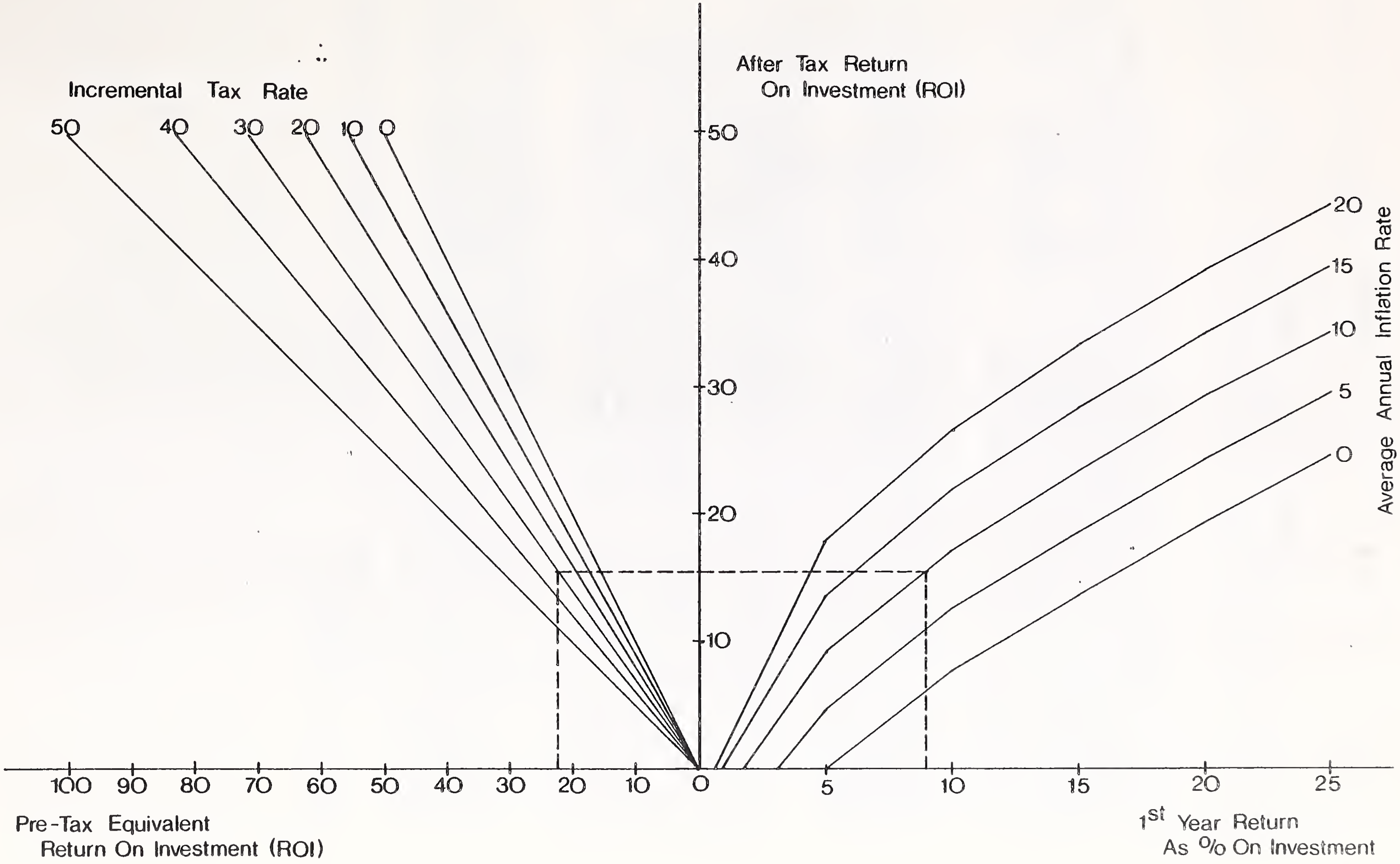
Suppose the inflation rate continues at about 10% a year. Figure 5 indicates that instead of just 8%, the return on investment from the windmill in our example will actually be 14%. This is, however, real savings of consumer dollars. Consequently this represents a savings of after-tax dollars, and is itself an after-tax rate of return. If the purchaser of the wind energy system is in the 35% tax bracket, for example, the equivalent pre-tax return is a full 21½%!

What does this mean? Let's look at this investment another way. Suppose that you have $3,800.00 jangling in your pockets. You are trying to decide whether to purchase a windmill, or to make some other investment. (Long trips to Bermuda get evaluated on those other criteria.) Projected wind speeds, annual savings and maintenance costs for a wind energy system installed at your site are similar to those in our example.

If you can find a savings plan or some other investment paying 21½% you may decide to put your money there. Each year you will collect interest income, pay taxes on that income, and pay for the electricity which could have been produced with a windmill. But the income from the investment will not be quite enough to pay for the electricity. So you will have to dip into the principal, the original $3,800.00, to pay the balance. At the end of each year you will have a little less remaining than you had a year before.

At the end of twenty years, our planning horizon, you will have nothing left, no savings, no interest income, and no windmill. Oh yes, you still have electric bills, considerably larger than they are

Return on Investment Chart



How To Use Figure 5

The chart shown here as Figure 5 provides a convenient way to estimate return on investment. First estimate the net savings you can expect during the first year you own your windmill. Net savings is equal to the value of the electricity produced minus any maintenance and operating costs.

Second, divide that number by the estimated installed cost of the wind generator. This provides an index of return for the first year, but does not reflect the increasing return you can expect as a result of inflation.

Locate the first year return estimate from your calculations on the right half of the bottom line of the Chart in Figure 5. Place a pencil at that point. Draw a line straight up until you intersect the curved line which represents the inflation rate you expect. Now draw a horizontal line to your left until it crosses the vertical bar or axis. You can read along the vertical line the return on investment which you can expect after taxes.

To determine the return you will realize before taxes, continue the line to the left until it crosses your incremental tax rate. Then draw a line straight down to the left half of the bottom line and read your pre-tax return.

The broken line on Figure 5 shows the return for our example.

today. Of course, if you chose the windmill it might wear out after twenty years too.

But in the meantime you will have a reasonably assured source of electricity. And savings accounts paying interest at the rate of 21½% are pretty hard to find.

The rate of return is, then, a measure of the productivity of an investment. If you, in our example, are able to identify an investment which, with equal levels of risk, will provide an interest income, or a rate of return, greater than 21½ per cent, that is the superior investment. If not, an investment in a wind energy system is your best option.

Again, return on investment is just one factor in your decision to purchase a wind machine. If the numbers at your site don't come out so well as our example that doesn't mean that you shouldn't purchase a windmill. But you should be aware of the return on investment you can expect, as well as other factors such as independence, beauty, a sense of pioneering spirit, which may be important to you as well.

IV. WINDMILL LIVING

A windmill is something you'll live with. You'll see it everyday and, unless your home is very secluded, so will your neighbors. In fact, this might be a good time to invite your neighbors over to tell them what you've learned about wind machines. They're likely to have some questions of their own about what it will be like having a windmill nearby. What impact will your wind energy system have on their environment and their safety? These are important questions and you should have some answers before you install a wind machine.

ENVIRONMENTAL IMPACT

Commonly expressed environmental concerns include noise, television interference, destruction of wildlife and aesthetics. A well-designed and well-maintained wind machine should not create serious problems in any of these areas.

Noise

Wind machines should not be noisy. The normal sound made by a properly running machine is a gentle swishing one, not any more distracting than rustling leaves or a spring shower.

Tests done by the U.S. government at Rocky Flats, Colorado, have shown windmills of a residential size produce sound in the range of 40 to 60 decibels. A decibel (dBA) is a unit for measuring sound. To provide some comparison, traffic in most cities measures 80 to 90 dBA, while normal speaking voices are in the range of 50 to 60 dBA. The wind itself can blow louder than 50 dBA.

Broadcast Interference

Radio and television interference, which can result from large wind turbines, is not a factor with residential machines. In fact, tests conducted at the University of Michigan suggest that residential machines with propellers made of wood or fiberglass will create no interference beyond 16 to 20 feet. A well-sited wind machine will be at least 30 feet from nearby structures. Television interference is, therefore, unlikely to be a problem.

Impact on Animals

A common concern involves the disturbance a windmill may cause neighborhood animals. Again, this has not proven a problem. Insects flying though propellers, as shown in tests performed by Battelle Laboratories, are buffeted a bit, but unharmed. Other tests, performed by the U.S. Department of Energy, have found that birds negotiate around revolving propellers very easily. There have even been reports of birds nesting quite comfortably just underneath wind machines.

Aesthetics

A more difficult issue involves aesthetics. While you may see in a windmill an object of delightful grace, your neighbors may not. People often find it hard to view changes to their environment as improvements. Perceptions of beauty tend to evolve. The philosopher Henri Bergson observed that people live with constant conflict between their desire for the excitement of change and their need for the security of sameness.

In Massachusetts the dilemma is profound. We have longstanding traditions for preserving our historic institutions and, at the same time, for spawning leading-edge technologies.

The erection of a windmill can punctuate this ever-present conflict because it is so visible a sign of the intrusion of change. It is also, however, a symbol of our traditional self-reliance. And so it is likely that wind machines will increase in use and, with time, become universally accepted.

SAFETY

Perhaps your neighbors will ask questions about safety. In fact, any new technology is bound to raise questions of safety and reliability. With reference to wind machines these questions usually involve the tower and the propellers.

Tower design and construction is a well-known technology, having been developed over a long period of time. If your tower has been engineered for your wind machine, has been installed by a reputable dealer and conforms to the requirements of the Massachusetts Building Code, the probability that it will collapse is extremely small. Even in the unlikely event of tower failure, the structure will usually collapse downward rather than pivoting on its base and toppling over. The threat to structures more than 30 feet away is, then, negligible.

There is no question that towers, especially the first ones in the neighborhood, are tempting challenges to many children. Remove the bottom climbing rungs to discourage jungle gym fans. Surround the tower with a fence. Prickly shrubs planted around the tower can also provide an effective deterrant.

Other safety questions involve wind machines falling apart and scattering pieces, particularly blades, around the neighborhood. Most commercially available machines have been tested by their manufacturers. While no system is perfectly fail-safe, the federal government has tested several machines at Rocky Flats, Colorado, under fairly extreme wind and weather conditions. Many manufacturers provide warranties. You should ask to see test results and have them explained until you are sure you understand them.

Wind machines have been known to throw a blade. The probability that this will happen to your machine depends both on the machine design and the care with which it is serviced. Blade failure usually results when undue stress is created by an out-of-balance propeller. You will soon become accustomed to the sound of your well-balanced machine. Any unusual change in that sound is a strong suggestion that a close inspection is warranted.

Ice can build up on the propellers creating stress through imbalance. The ice itself can melt loose, and can be thrown some distance by a rotating propeller. It is a good idea to observe your machine closely throughout the winter, and to shut it down completely if you see ice forming on the blades.

As an early precaution, you should check your insurance coverage with the company carrying your home owner's policy. Some policies do cover damage which might be caused by a wind machine. If yours does not, you should change it.

Consider and answer carefully your neighbors' questions. They may help you discover something you've missed.

V. THE FINAL PREPARATIONS

The wind industry has grown a great deal in the last few years, making really remarkable progress. Nonetheless, it is still a young industry whose support services - spare parts outlets, servicing outlets, marketing organizations - are still developing.

When considering a windmill for your own use, you will need to learn as much as you can about manufacturers and dealers. You should find out about warranties and service contracts. It may be difficult finding an experienced dealer, but if you can you will want to talk to former customers (See Appendix VI for a checklist to guide selection of manufacturers and dealers).

You will need to speak to government officials in your area. A building permit will be needed to erect a tower, and your tower must meet engineering standards for its design and installation. In most communities, the building inspector enforces both the building and the zoning codes.

Local zoning laws vary widely around the state. Often, the bylaws don't specifically provide for wind machines. The Massachusetts Executive Office of Energy Resources has, however, provided a guidebook for local zoning officials which has been distributed throughout the state. If your town has adopted these recommendations, it will be easier for you to determine if your site conforms to zoning requirements. In other communities, you may find your application providing a precedent.

There are a few special instances. Any installation in a wetlands area must be reviewed by the local conservation commission pursuant to the Wetlands Act. Any installation in an historic district must be reviewed by the local historic district commission to be sure that it is compatible with the preservation of the area. Installations near airports may pose special problems. Those within 20,000 feet of any landing strip must be reviewed by both the Federal Aviation Administration and the Massachusetts Aeronautics Commission.

Review your plans with your local utility. Their primary concern is safety. Your utility will want to be certain that their employees servicing lines in your area will be protected from unexpected power surges from your wind machine. While most single-phase, 2 kw to 10 kw machines described above cannot produce power when a utility line is down, it is wise to double check.

Evaluate all of the factors carefully. Talk to several dealers about several brands and models. Learn as much as you can. In the long run, the more you know about wind machines and how they perform, the better the chances that you will make a good purchase decision.

SUMMARY

A wind energy system may be appropriate for you. You need, however, to make a thorough and objective evaluation before that system is installed. This check list summarizes the major points we have discussed:

1. Understand how the wind machine you buy operates and the relationship between wind conditions and the equipment you will use to produce electricity.
2. Conduct as precise an assessment of wind conditions at your site as possible.
3. Analyze your electrical consumption and reduce it.
4. Carefully evaluate the financial benefits you expect and the costs you are likely to incur.
5. Be sure that your wind machine will be accepted in your neighborhood.
6. Review your installation with the building inspector in your community as well as other involved government agencies.
7. Select a manufacturer and dealer carefully.

Wind, water, sun - with modern technological advances, each holds forth the promise of abundant, clean and affordable energy. The successful use of these technologies depends upon matching needs with resources at the places where those resources naturally occur.

Some Massachusetts homeowners will find a match between their electrical need and the wind resource in their own backyards. For you, the installation of a windmill can herald a pioneering adventure.

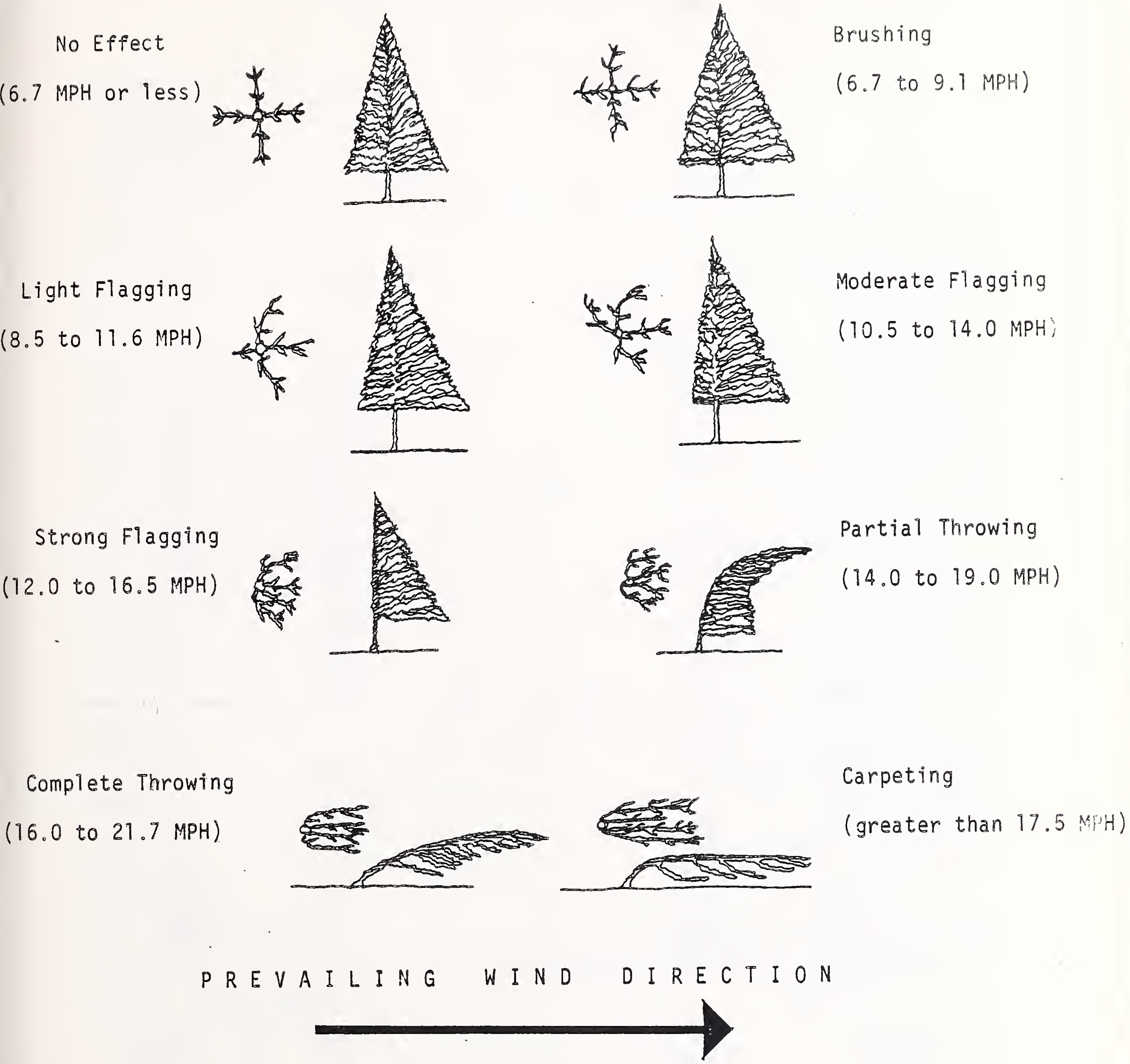
APPENDIX I

WIND DATA FROM SELECTED NATIONAL CLIMATE CONTROL STATIONS IN MASSACHUSETTS

Station	Station Name	Station Elevation (Ft.)	Anemometer Height (Ft.)	Average Wind Speed at Anemometer (m.p.h.)	Average Wind Speed at 33 Feet
Bedford, MA	L.C. Hanscom Fld	144	13	6.9	8.1
Boston, MA	Logan Airport	33	32	13.2	13.2
Chicopee, MA	Westover AFB	245	15	6.3	6.9
Falmouth, MA	Otis AFB	137	10	9.4	11.2
George's Shoals MA	Texas Twr. 2	32	200	20.8	16.1
Nantucket, MA	Nantucket Airport	46	20	13.7	14.6
Nantucket, MA	Texas Twr. 3	85	200	19.9	15.2
S. Weymouth, MA	S. Weymouth Navy Station	154	16	7.4	8.3
Westfield, MA	Barnes Airport	278	56	8.3	7.6
Worcester, MA	Worcester Airport	997	26	13.2	13.7

APPENDIX II

GRIGGS-PUTNAM INDEX



Expected Interval of Average Annual Wind Speed (MPH)

APPENDIX III

GRUMMAN CORPORATION TABLE OF AVERAGE ANNUAL ENERGY REQUIREMENTS OF 100 VOLTS ELECTRICAL APPLIANCES

(Consumption is based on normal usage and an average family of four.)

	Average Watts (W)	Annual Kilowatt Hours (kwh)
FOOD PREPARATION		
Blender	385	15
Broiler	1,436	100
Carving Knife	92	8
Coffee Maker	894	106
Deep Fryer	1,448	83
Dishwasher	1,201	383
Egg Cooker	516	14
Frying Pan	1,196	185
Hot Plate	1,257	90
Mixer	127	13
Oven (microwave)	1,450	190
Range with oven	12,200	1,175
with self cleaning oven	12,200	1,205
Roaster	1,333	205
Sandwich Grill	1,161	33
Toaster	1,146	39
Trash Compactor	400	50
Waffle Iron	1,116	22
Waste Disposer	445	30
FOOD PRESERVATION		
Freezer (15 cu. ft.)	341	1,195
Freezer (12 cu. ft.) (frostless)	440	1,176
Refrigerator (12 cu. ft.)	241	725
Refrigerator (12 cu. ft.) (frostless)	321	1,217
Refrig./Freezer (14 cu. ft.)	326	1,137
Refrig./Freezer (14 cu. ft.) (frostless)	615	1,829
HEALTH AND BEAUTY		
Hair Dryer	381	14
Shaver	14	1.8
Toothbrush	7	0.5
Vibrator	40	2
HOME ENTERTAINMENT		
Radio	71	86
Radio	109	109
Television B/W tube type	160	350
Television B/W solid state	55	120
Television Colour tube	300	660
solid state	200	440

APPENDIX III (Cont'd)

	Average Watts (W)	Annual Kilowatt (kwh)
HOUSEWARES		
Clock	2	17
Floor Polisher	305	15
Sewing Machine	75	11
Vacuum Cleaner	630	46
LIGHTS		
75 Watt Blubs (8 each)	600	864
LAUNDRY		
Clothes Dryer	4,856	993
Iron (hand)	1,008	144
Washing Machine (auto)	512	103
Washing Machine (non-auto)	286	75
Water Heater	2,475	4,219
Water (quick recovery)	4,475	4,811
COMFORT CONDITIONING		
Air Cleaner	50	216
Air Conditioner (room)	1,565	1,889
Bed Covering	177	147
Dehumidifier	257	377
Fan (attic)	370	281
Fan (circulating)	83	43
Fan (rollaway)	171	138
Heater (portable)	1,322	178
Heating Pad	65	10
Humidifier	177	163
TOOLS		
1/4" Drill	250	2
Sabre Saw	325	1
Circular	1,000	5
Typewriter	40	7
Water Pump (1/3 HP)	420	150
3" Sander, Belt	770	10
ELECTRIC HOME HEATING		
Measured Living Area		
1,000 sq. ft.	17,000	16,300
1,500 sq. ft.	21,500	20,800
2,000 sq. ft.	26,000	25,500

APPENDIX IV

WIND ENERGY SYSTEM OUTPUT

	RATED POWER				
Adjusted Annual Average Wind Speed (mph)	2KW	4KW	6KW	8KW	10KW
	SWECS Annual Output in KWh				
10.0	2800	4000	5900	7800	9800
10.5	3200	4700	7000	9300	11600
11.0	3600	5400	8100	10700	13300
11.5	4000	6100	9100	12000	14900
12.0	4500	6800	10000	13300	16600
12.5	4800	7500	11100	14700	18500
13.0	5200	8200	12300	16400	20400
13.5	5600	8900	13400	17900	22300
14.0	6000	9600	14200	18800	24200
14.5	6400	10300	15600	20900	26200
15.0	6800	11100	16800	22500	28100
15.5	7100	11800	17900	24000	30100
16.0	7400	12600	19100	25600	32000
16.5	7700	13200	10500	27800	34000
17.0	7900	13800	21200	28600	36000
17.5	8200	14400	22100	29800	37500
18.0	8500	15000	22700	30400	38000
18.5	8650	15500	23500	31500	39400
19.0	8800	16000	24300	32600	40900
19.5	8950	16500	25100	33600	42300
20.0	9100	17000	25900	34800	43800

APPENDIX V

ECONOMIC ANALYSIS WORKSHEET

1. System Cost

Wind Turbine	$____________________
Tower	$____________________
Installation	$____________________
Inverter if applicable	$____________________
Total System Cost	$____________________ A.

2. Tax Credits

Federal Energy Credit	.4 x A. = $____________________ B.	(up to $4,000)
State Energy Credit	.35 x (A - B) = $______________ C.	(up to $1,000)

3. Net Installed System Cost After Taxes

A. x B. - C. = $______________ E.

4. Annual Maintanence and Operating Costs (2.5%)

.025 x A. = $_________________ F.

5. Net Annual Savings

(________________kwh x __________________$/kwh) - F. = $________________ G.

WECS Annaul Energy Output	Current Electricity Rate

6. Return on Investment

$\frac{\text{Net Annual Savings}}{\text{Net Installed Cost}} = \frac{G.}{E.} =$ __________ x 100 = __________%

See Figure 5 for Return on Investment graph.

APPENDIX V

ECONOMIC ANALYSIS WORKSHEET

(Example #1, 10 KW Wind Machine)

1. System Cost

Wind Turbine	$ 12,000
Tower	$ 1,500
Installation	$ 3,000
Inverter if applicable	$ 3,500
Total System Cost	$ 20,000 A.

2. Tax Credits

Federal Energy Credit .4 x A. = $ 4,000 B. (up to $4,0

State Energy Credit .35 x (A - B) = $ 1,000 C. (up to $1,0

3. Net Installed System Cost After Taxes

A. x B. - C. = $ 15,000 E.

4. Annual Maintanence and Operating Costs (2.5%)

.025 x A. = $ 500 F.

5. Net Annual Savings

(18,000 kwh x .095 $/kwh) - F. = $ 1,210 G.

WECS Annaul Energy Output — Current Electricity Rate

6. Return on Investment

$\frac{\text{Net Annual Savings}}{\text{Net Installed Cost}} = \frac{G.}{E.} =$ .081 x 100 = 8.1 %

See Figure 5 for Return on Investment graph.

APPENDIX V

ECONOMIC ANALYSIS WORKSHEET

(Example #2, 1.8 KW)

1. System Cost

Wind Turbine	$ 4,000	
Tower	$ 1,100	
Installation	$ 1,900	
Inverter if applicable	$	
Total System Cost	$ 7,000	A.

2. Tax Credits

Federal Energy Credit .4 x A. = $ 2,800 B. (up to $4,000)

State Energy Credit .35 x (A - B) = $ 1,000 C. (up to $1,000)

3. Net Installed System Cost After Taxes

A. x B. - C. = $ 3,200 E.

4. Annual Maintanence and Operating Costs (2.5%)

.025 x A. = $ 175 F.

5. Net Annual Savings

(3,800 kwh x .09 $/kwh) - F. = $ 167 G.

WECS Annaul Energy Output
Current Electricity Rate

6. Return on Investment

$$\frac{\text{Net Annual Savings}}{\text{Net Installed Cost}} = \frac{G.}{E.} = .052 \times 100 = 5.2\ \%$$

See Figure 5 for Return on Investment graph.

APPENDIX VI

MANUFACTURER AND DEALER SELECTION CHECKLIST

The following checklist summarizes the major points discussed in the text which you will want to have in mind in selecting a manufacturer and a dealer.

Manufacturer Selection

1. Warranties: duration and extent vary
2. Specifications: Manufacturers' specifications are not provided in a standardized format. Be sure to look them over carefully and ask questions until you are sure you understand them.
3. Test data: Most manufacturers should be able to provide you with extensive test data. Review it and, again, ask questions until you are sure you understand it.
4. Customer references: It is always helpful to talk with someone like yourself who has already experienced using a similar system.

Dealer Selection

1. Service: Is the dealer willing to service the wind energy system you are buying? Is equipment readily available to the dealer to service your machine? Has the dealer had experience with servicing your equipment? Is a service contract available?
2. Customer references: Can you talk with some one who has had experience with this dealer?
3. Other installations: How many other wind machines has the dealer installed and how well are they working?